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Contributions to the knowledge of Swedish forest collembola

with notes on seasonal variation and alimentary habits

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ROYAL COLLEGE OF FORESTRY

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INTRODUCTION

Few investigations exist on Swedish forest collembola. AGRELL (1934, 1941) studied the composition of the collembolan fauna of needle litter of spruce and pine in Eastern Skåne and of needle litter of pine and of litter and substratum of birch forests in Swedish Lapland. FORSSLUND (1944, 1945) studied, besides other invertebrate groups, the collembola of North Swedish forest soils. BÖDVARSSON (1961) studied the collembola of deciduous and coniferous forests in Southern Sweden. Otherwise, very sporadic information exists on forest collembola in Sweden.

The present author has collected some material of collembola in Swedish forests, both in deciduous and coniferous forest areas. The following scheme gives a survey of the areas of collection and their distribution among deciduous and coniferous forests (see descriptions p. 4-6).

Southern Sweden	Dalby Hage Trollskogen	deciduous
	Bökeberg Sjöbo	coniferous
Northern Sweden	Långmor, Hälsingland	coniferous

The aim of these investigations has been firstly to obtain information on the qualitative and quantitative composition of the collembolan faunas of various Swedish forest areas and to try to ascertain, if there are any special forest collembola species in these areas.

Secondly some studies have been made on the vertical distribution and the seasonal variations of the species of the areas studied. Thirdly, some alimentary studies have been made on the collembola from Hälsingland.

The material has been collected as soil samples which have been treated in Berlese funnels. The samples were in general 400 cm^3, but if the litter layer was very thick, they were somewhat larger. In general samples were taken separately from the litter layer and the underlying humus layer.

The following species have been found in the present material of Swedish forest collembola.

Hypogastrura manubrialis (Tullberg)
Hypogastrura purpurescens (Lubbock)
Xenylla börneri Axelson
Xenylla brevicauda Tullberg
Xenylla maritima Tullberg
Xenylla grisea Axelson
Xenylla humicola (O. Fabricius)
Xenylla mucronata Axelson
Willemia aspinata Stach
Willemia anophthalma Börner
Friesea mirabilis (Tullberg)
Friesea claviseta Axelson
Pseudachorutes corticicolus (Schäffer)
Pseudachorutes parvulus Börner
Pseudachorutes subcrassus Tullberg
Anurida granulata Agrell
Micranurida pygmaea Börner
Micranurida forsslundi Gisin
Neanura muscorum (Templeton)
Onychiurus absoloni (Börner)
Onychiurus furcifer (Börner)
Onychiurus armatus (Tullberg), sensu Bödvarsson 1970
Onychiurus ambulans (L.) Stach
Tullbergia krausbaueri (Börner)
Tullbergia callipygos Börner
Anurophorus laricis Nicolet
Pseudanurophorus binoculatus Kseneman
Folsomia quadrioculata (Tullberg)
Folsomia fimetaria (Linné)
Folsomia litsteri Bagnall

Isotomiella minor (Schäffer)
Pseudisotoma sensibilis (Tullberg)
Vertagopus cinerea (Nicolet)
Isotoma bipunctata Axelson
Isotoma notabilis Schäffer
Isotoma viridis Bourlet
Isotoma olivacea Tullberg
Isotoma violacea Tullberg
Entomobrya albocincta (Templeton)
Entomobrya corticalis (Nicolet)
Entomobrya nivalis (Linné)
Orchesella flavescens (Bourlet)
Orchesella cincta (Linné)
Orchesella bifasciata Nicolet
Heteromurus nitidus (Templeton)
Lepidocyrtus cyaneus Tullberg
Lepidocyrtus lanuginosus (Gmelin)
Pseudosinella alba (Packard)
Tomocerus flavescens (Tullberg)
Tomocerus minor (Lubbock)
Neelus minutus Folsom
Megalothorax minimus Willem
Sminthurides pumilis (Krausbauer)
Sminthurinus elegans (Fitch)
Sminthurinus aureus (Lubbock)
Bourletiella hortensis (Fitch)
Sminthurus lubbocki Tullberg
Sminthurus fuscus (Linné)
Dicyrtoma minuta (O. Fabricius)
Dicyrtoma fusca (Lucas)

1. Short descriptions of the forest areas studied

1.1. Dalby Hage

Dalby Söderskog or Dalby Hage, as it is usually called now, lies about 11 km E of Lund, Skåne, in the parish of Dalby. It is a mixed deciduous forest, the most important trees being oak, beech, elm and ash. Hazel

and hawthorn are the most important species of bushes. In the areas where the present material was collected, beech was the dominant tree.

The whole area of Dalby Hage is covered with baltic moraine. It is rich in lime and clay, the surface layers of the moraine thus being more or less clayey.

Dalby Hage is very old as a forest area. Especially the oaks have existed there for a very long time, at least since the close of the Middle Ages. Most of the now living oaks go back to the beginning of the 18th century. The beech is also very old in Dalby Hage. It was there already at the beginning of the 16th century. Beeches cover about 16 per cent of the area. The oldest elms go back to the latter half of the 18th century. Most of the elms are however younger and have grown up at the beginning of the 19th century or later. The largest now living ashes go back to the beginning of the 19th century.

The hazel is very common in Dalby Hage, especially in the oak areas, and covers a little more than one third of the whole area.

The ground vegetation comprises about 200 species. Of these the most common are *Anemone nemorosa, A. ranunculoides, Gagea lutea, G. minima, G. spathacea, Pulmonaria officinalis, Ranunculus ficaria* and *Mercurialis perennis*.

Dalby Hage was placed under protection as a national park ("national-park") in 1918.

The material of Dalby Hage was collected between 26.2 and 4.10.1966.

1.2. Trollskogen

The Trollskogen forest (or Gryteskogen, as it is also called) lies about 12 km E of Lund and 4 km N of Dalby, Skåne.

The dominating tree is beech, partly of a special variety, *Fagus silvatica* var. *tortuosa*. Single oaks occur. In depressions alder-marshes occur. The trees are of very different age, probably between 20 and 120 years.

There are no bushes. The ground vegetation is dominated by *Lamium galeobdolum, Stellaria holostea, Anemone nemorosa.* In moister areas the flora is somewhat richer.

The area is covered by a very stony and sandy moraine. There is a thin F-layer and a humus layer.

The material from Trollskogen was collected between 12.3 and 24.6. 1966.

1.3. Bökeberg

The Bökeberg area lies about 18 km ESE of Malmö, Skåne. It is a spruce-plantation of about 50 years´age. There is a sparse bush-vegetation of single specimens of *Sambucus racemosa* and *Sorbus aucuparia.*

The ground vegetation is dominated by *Oxalis acetosella, Maianthemum bifolium, Rubus idaeus* and *Epilobium angustifolium.* In depressions *Dryopteris dilatata* may dominate. Here and there are great clumps of *Pteridium aquilinum.*

The area is covered by sandy moraine. Beneath the litter layer there is a humus layer of about 2-3 cm, and then follows a 15 cm layer of sand mixed with humus, more or less soaked in the upper part. Then there are darker B and C layers.

The material of Bökeberg was collected between 26.2 and 9.11.1966.

1.4. Sjöbo

The area studied lies several kilometers W of the market-town Sjöbo in Skåne. It is a spruce-plantation of about 50 years´age. There is no bush-vegetation. The ground vegetation is dominated by *Oxalis acetosella* and *Rubus idaeus.* Also *Epilobium angustifolium, Dryopteris spinulosa* and *D. dilatata* occur.

The area is situated on sandy layers of high fertility. The humus layer is about 2-3 cm thick. Then there follows a little soaked sand mixed with humus (10-15 cm) and then darker B and C layers.

The material from Sjöbo was collected in June 1966.

1.5. Långmor

The forest area studied lies close to the farm Långmor in the NW-part of the parish Bjuråker in the province of Gävleborg (northern Hälsingland).

Pine is the completely dominating tree. Single spruces and alders occur. The ground vegetation is dominated by *Vaccinium myrtillus* and *Vaccinium vitis-idaea*. There is some occurrence of *Calluna vulgaris*. The most common moss is *Pleurozium schreberi*, less common are *Hylocomium splendens* and *Dicranum undulatum*.

The soil-type is sandy moraine. On the top of this lies a layer of a thickness of about half a metre consisting of a material varying between sand and gravel. The thickness of the humus layer varies between 3.0 and 3.5 cm. The pH of both litter and humus layers is 3.9.

The material from Långmor was collected in June 1970.

The description of Dalby Hage is taken from WEIMARCK (1960), that of Långmor from GILLIUSSON and THELANDER. Fil dr B. NIHLGÅRD, Botanical Institute, University of Lund, has contributed to the descriptions of Trollskogen, Bökeberg and Sjöbo.

2. The faunas of the different forest areas

2.1. The deciduous forest areas

The collembola of the two areas with deciduous forest are listed in tables 1 and 2. The tables show the number of samples in which each species has been found and the total number of specimens of each species. It is seen that in Dalby Hage 32 species were found in 27 samples, whereas in Trollskogen 35 species were found in 20 samples. Thus, the collembolan fauna of Trollskogen is somewhat richer in species than that of Dalby Hage, showing 1.8 species per sample as compared with 1.2 species per sample in Dalby Hage.

When the composition of the two faunas is compared, it is seen that 22 species (table 3) are common to both faunas. Ten of these species

(the first ten of the table) are exactly the same as the ten most common species of collembola in South Swedish soils in general, according to BÖDVARSSON (1961). (See table 1 in this work). This shows very distinctly that it is impossible to designate any characteristic dominating species of these deciduous forests. The material of collembola from deciduous forests treated in BÖDVARSSON (1961) comprises 56 species from 33 samples. This means 1.7 species per sample or approximately the same variety of species as in Trollskogen. All the species common to Dalby Hage and Trollskogen also occur in the material from deciduous forests in BÖDVARSSON 1961 with the exceptions of *Sminthurinus aureus, Micranurida pygmaea, Pseudachorutes parvulus* and *Onychiurus absoloni*. The general conclusion of this comparison is, that the dominating part of the collembola species of deciduous forests in Southern Sweden are ubiquitous species which are very common in many other soil and vegetation types.

Of course there are differences in the composition of the two faunas, but the differing species mostly occur in only one or two samples and in a few specimens. Such sporadic occurrence is very common and can scarcely be used in characterizing the fauna of a certain type of environment.

In Dalby Hage, several species occur, however,in some quantities, which have not been found in Trollskogen. These are: *Hypogastrura purpurescens, Neelus minutus, Isotoma olivacea* and *Dicyrtoma minuta. Tullbergia callipygos* and *Pseudanurophorus binoculatus* were found in 30 per cent of the samples in Trollskogen but not in Dalby Hage. In the material from deciduous forests in BÖDVARSSON 1961, almost half of the species occur only in a single or a pair of samples. According to this material the species *Hypogastrura purpurescens, Tomocerus longicornis, Willemia aspinata, Orchesella flavescens* and *Onychiurus furcifer* occur predominantly in the litter of deciduous forests in Southern Sweden (p.191). In the present material *Hypogastrura purpurescens* was found only in Dalby Hage, *Tomocerus longicornis* was not at all found, *Willemia aspinata* was found in both places in very small amounts, and *Orchesella flavescens* was found only in Trollskogen in a single specimen. *Onychiurus furcifer* was however found both in Dalby Hage and in Trollskogen. It is among the most common species in Dalby Hage, found in 85 per cent of

the samples. It has, in a way, replaced *Onychiurus armatus* in this locality. In Trollskogen the roles of these two species are exchanged.

A similar case is *Tullbergia krausbaueri*, which is among the most common species in Trollskogen. It is found only in a single sample in two specimens in Dalby Hage.

AGRELL (1941) studied the composition of the collembolan fauna of the litter and humus of birch forests in Swedish Lapland. The dominant species were all ubiquitous: *Onychiurus armatus*, *Folsomia quadrioculata*, *Isotomiella minor*, *Isotoma notabilis*, *Isotoma viridis*, *Lepidocyrtus lanuginosus*, i.e. the same species which most often dominate deciduous forest soils in Southern Sweden.

The net result of these comparisons must be, that it is impossible to designate any distinct species as a characteristic specialist of the litter and humus of deciduous forests in Southern Sweden. Quantitatively dominant are great ubiquists as *Isotoma notabilis*, *Lepidocyrtus lanuginosus*, *Folsomia quadrioculata*, *Isotomiella minor* and *Onychiurus armatus*. Some of these may in some areas be substituted by other less common species as *Onychiurus furcifer* in Dalby Hage. A considerable amount of species occurs very sporadically and are found in a single or a pair of samples and cannot therefore be characteristic of the soil type. The remainder are more or less ubiquitous species of less common occurrence than the great ubiquists.

In Trollskogen four samples were taken of pieces of beech-bark with thin sheets of green moss. The fauna of this medium is shown in table 4. *Pseudisotoma sensibilis* and *Lepidocyrtus lanuginosus* occur in all four samples, *Friesea claviseta* and *Xenylla börneri* occur in three samples whereof *Xenylla* occurs in the vast number of 2120. *Pseudisotoma sensibilis* was previously known as preferring mossy vegetation of different kinds (cf BÖDVARSSON 1957, 1961). It is evidently also common in moss sheets on bark. *Lepidocyrtus lanuginosus* is a very well known ubiquist, occurring in the soil as well as up in the higher vegetation, evidently also in moss on bark. *Friesea claviseta* shows some preference for mossy vegetation according to BÖDVARSSON 1961. *Xenylla börneri* was the dominant species of thin and dry mossy sheets on stones according to BÖDVARSSON 1961 and this is evidently also the case with mossy sheets

on bark. Of the remainder of the species, *Entomobrya corticalis*, *Vertagopus cinerea* and *Orchesella bifasciata* are known as either corticicolous or moss-living (cf GISIN 1960 and BÖDVARSSON 1961), the rest being more or less ubiquitous. Thus, it is seen that the moss sheets on beech-bark are inhabited by a series of species of which several are more or less specialized on this medium.

2.2. The coniferous forest areas

The material of collembola from coniferous forests comes from three areas, two in Southern Sweden, namely Bökeberg and Sjöbo in Skåne, and one from Northern Sweden, namely Långmor in Hälsingland. The composition of the faunas is shown in tables 5, 6 and 7. It is seen that in Bökeberg, 32 species were found in 34 samples, in Sjöbo 17 species were found in 10 samples, and in Hälsingland 21 species were found in 36 samples. This makes an average of 0.9 species per sample in Bökeberg but only 0.6 species per sample in Hälsingland. As the number of samples is roughly the same in both areas, it is seen that the fauna is poorer in species in Hälsingland than in Skåne, and poorer than that of deciduous forests.

When the faunas of Sjöbo and Bökeberg are compared it is seen that there are considerable differences in their composition. If we look first at the fauna of Bökeberg, it is seen that the 9 most common species with the exception of *Onychiurus absoloni*, belong to the group of the 12 most common collembola species in South Swedish soils in general (BÖDVARSSON 1961, p. 179-182). This shows that the fauna of Bökeberg is generalized, the bulk of the specimens belonging to very ubiquitous species. *Onychiurus absoloni* is the only one of the more common species which is not a great ubiquist in Southern Sweden (BÖDVARSSON 1961 under the name *Onychiurus affinis*). *Onychiurus absoloni* occurs in a considerable number of samples in all three coniferous forest areas now studied. Of other species occurring more than sporadically, *Xenylla brevicauda* is known as preferring needle litter and in BÖDVARSSON 1961 it was only found in this medium.

The fauna of Sjöbo is somewhat more specialized than that of Bökeberg. It is quantitatively dominated by the three species *Isotoma notabilis*, *Isotomiella minor* and *Xenylla humicola*. The first two species are

extremely great ubiquists, as is seen from BÖDVARSSON 1961, but *Xenylla humicola* is a rather uncommon species and not at all frequent in coniferous forests. *Onychiurus absoloni* also occurs in Sjöbo as in Bökeberg in half of the samples, yet in small quantities. Otherwise the fauna is generalized. The great ubiquist *Folsomia quadrioculata* occurs in only one specimen in the whole material.

The fauna of 9 samples from coniferous litter in Sothern Sweden was analyzed in BÖDVARSSON 1961. This fauna is very generalized, all the most common species being great ubiquists. *Onychiurus absoloni* occurs in one-third of the samples.

The fauna of the coniferous forest in Hälsingland differs from the two southern faunas in that it is quite dominated by a single species, *Anurophorus laricis*, which occurs in all 36 samples analyzed.

Anurophorus laricis is generally known as a corticicolous animal, but is also often found in the soil. In BÖDVARSSON 1961 it was found most often in grassy and mossy soil, but only once in coniferous litter. All the other species occurring in considerable quantities in the present material are typical ubiquists (cf BÖDVARSSON 1961). *Onychiurus absoloni* occurs in 11 of 36 samples. This species is the only one of the non-ubiquists which occur regularly and in some quantity in all coniferous forest localities examined in the present work. It thus seems to show a certain preference for coniferous forests.

AGRELL (1941) studied the collembola of needle litter of pine in Swedish Lapland. He found that the fauna was dominated by *Anurophorus laricis*. This species composed 85 per cent of all individuals in the uppermost layer (0-2 cm). This is a close parallel to the conditions in Hälsingland. AGRELL (1934) found that *Anurophorus laricis* also dominated the needle litter of pine he studied in Eastern Skåne. On the other hand he never found this species in needle litter of spruce (AGRELL 1934, 1941), and this is also the case in the present material. AGRELL (1941) found in less numbers, besides *Anurophorus laricis*, the species *Beckerella inermis, Xenylla brevicauda, Friesea mirabilis, Vertagopus cinerea* and *Entomobrya marginata*. Other species, also the ubiquitous ones, occurred in very small numbers. Of these species, only *Xenylla brevicauda* and *Friesea mirabilis* are found in the present material.

In the pine litter of Eastern Skåne, AGRELL found *Anurophorus laricis*, *Xenylla brevicauda* and *Entomobrya nivalis* as dominant species. In the spruce litter he found *Xenylla brevicauda*, *Lepidocyrtus lanuginosus*, *Isotoma notabilis* and *Entomobrya nivalis* as dominant species.

FORSSLUND (1944) found 30 species of collembola during his very detailed and comprehensive studies of mostly mixed pine-spruce forest soils in Västerbotten. Of these, only 7 species have not been found in the present material from coniferous forests and among these only the species *Pseudachorutes subcrassus*, *Folsomia fimetarioides* and *Arrhopalites pygmaeus* are characterized as common by FORSSLUND.

The following species are characterized as common and numerous: *Isotoma notabilis*, *Isotomiella minor*, *Pseudanurophorus binoculatus*, *Tullbergia krausbaueri*, *Onychiurus armatus*, *Onychiurus absoloni*, *Micranurida pygmaea* and *Willemia anophthalma*. It is seen that *Isotoma notabilis*, *Isotomiella minor*, *Tullbergia krausbaueri*, *Onychiurus armatus* and *Onychiurus absoloni* are among the most common species in the present material from coniferous forests. *Pseudanurophorus binoculatus*, *Micranurida pygmaea* and *Willemia anophthalma* are less common and numerous in the present material. The species *Friesea mirabilis*, *Lepidocyrtus lanuginosus* and *Megalothorax minimus* are characterized by FORSSLUND as very common but occurring in very small numbers or only single specimens. It is seen that *Lepidocyrtus lanuginosus* and *Friesea mirabilis* are very common and numerous in the present material. *Megalothorax minimus* is less common but occurs both at Bökeberg and Sjöbo. *Anurophorus laricis*, which dominates the fauna in Hälsingland, was also found by FORSSLUND in Västerbotten, but it was not very common or numerous. It was found in great quantities in only one sample from litter. It was also found up in the trees.

These comparisons show, that the collembolan fauna of coniferous forests is somewhat more specialized than that deciduous forests. The great ubiquists *Lepidocyrtus lanuginosus*, *Isotoma notabilis*, *Folsomia quadrioculata*, *Tullbergia krausbaueri*, *Friesea mirabilis* and *Isotomiella minor* are generally dominating but species, which are uncommon in other surroundings may become quite conspicuous in certain areas (*Xenylla humicola* in Sjöbo, *Anurophorus laricis* in Hälsingland and especially *Onychiurus absoloni* in all three areas studied).

At Bökeberg spruce cones were collected at 5 localities and their fauna of collembola extracted in Berlese funnels. This fauna is shown in table 8. It is seen that all important species of this fauna are ubiquists which occur in great quantities in many soil and vegetation types. *Onychiurus absoloni* has, however, shown a certain preference for coniferous litter. The spruce cones therefore evidently do not represent any extreme type of medium which favours any ecologically specialized species.

3. Vertical distribution and seasonal variation

3.1. Vertical distribution

Samples have been taken separately from the overlying litter layer and the underlying humus layer in the deciduous forests of Dalby Hage and Trollskogen and the coniferous forests of Sjöbo, Bökeberg and Hälsingland. It is therefore possible to obtain some idea of the depth distribution between these two layers of the most common species.

If we look at the decidous forest area of Dalby Hage (table 9), both *Folsomia quadrioculata, Isotoma notabilis, Onychiurus furcifer* and *Isotomiella minor* occur in somewhat greater numbers of samples in the humus, but in a definitely greater number of specimens in the litter. This must mean that these species are approximately as common in both litter and humus, but the population density is greater in the higher layers. *Isotomiella minor* is, however, most evenly distributed among the two layers and this is in accordance with the generally known tendency of this white and blind species to prefer the deeper layers.

Lepidocyrtus lanuginosus and *Tomocerus flavescens* show a definitely higher preference for the higher layers than for the lower ones, and this is in accordance with previous knowledge of these species. The material of the remaining species is smaller but most of them show a tendency to a greater concentration in the litter layer.

In the Trollskogen area (table 10) a very similar depth distribution as in the previous area is seen for the species *Isotoma notabilis, Lepidocyrtus lanuginosus, Folsomia quadrioculata, Isotomiella minor* and *Tomocerus flavescens*. The preference of *Isotomiella minor* for the deeper

layers is more distinct here than in Dalby Hage. Two species occurring in Trollskogen, which were not found in Dalby Hage, show a very distinct preference for the deeper layers. These are the white and blind *Tullbergia krausbaueri* and *Onychiurus armatus*. This is in accordance with previous experience from these species (see AGRELL 1941, PALISSA 1959, HAARLÖV 1960). Of the remaining species, *Neanura muscorum* and *Onychiurus furcifer* show preference for the higher layers (cf *Onychiurus furcifer* in Dalby Hage), the others occur in too small quantities to allow any definite conclusions.

If we look at the coniferous forest area at Sjöbo (table 11), it is seen that *Isotoma notabilis, Xenylla humicola, Neanura muscorum, Onychiurus absoloni* and *Lepidocyrtus lanuginosus* occur in greater numbers in the litter layer. *Isotomiella minor, Tullbergia krausbaueri* and *Onychiurus armatus* occur predominantly in the humus layer, the latter two only there. This is in accordance with the previous knowledge of the depth preferences of these white and blind species. It is rather peculiar that *Onychiurus absoloni* only occurs in the litter layer in Sjöbo, as it occurs predominantly in the humus layer in Hälsingland (table 13).

In the coniferous forest at Bökeberg (table 12), the species *Lepidocyrtus lanuginosus, Isotoma notabilis, Folsomia quadrioculata, Isotomiella minor, Onychiurus armatus, Isotoma viridis, Lepidocyrtus cyaneus* and *Pseudosinella alba* occur in the greatest numbers in the litter layer. It is rather peculiar that *Isotomiella minor* and *Onychiurus armatus*, being white and blind, occur in greater numbers in the litter than in the humus. They were more numerous in the humus at Sjöbo. It may be pointed out here, that HAARLÖV (1960) found that *Isotomiella minor* had the same vertical distribution as *Folsomia quadrioculata* and occurred in greatest numbers in the A-layers and the upper part of the subsoil (the uppermost 3 cm). A similar result found PALISSA (1959).

Tullbergia krausbaueri is more numerous in the humus as is to be expected. *Friesea mirabilis* and *Onychiurus absoloni* are rather evenly distributed between litter and humus.

In Hälsingland (table 13) the dominant species, *Anurophorus laricis*, occurs in the same number of samples in both layers, but in much greater number of specimens in the litter layer (678 and 432 respectively).

This must mean that the species is present all over in the soil but its population density is greatest highest up in the soil. This has of course relation to the xerophilous way of living of this species. It is generally known as a corticicolous animal. (GISIN 1960).

Two other species show distinct preference for the litter layer, namely *Xenylla börneri* and *Entomobrya nivalis*. *Xenylla börneri* is a xerophilous species preferring vegetation of moss and lichens on stones and tree-trunks (GISIN 1960). In the material of BÖDVARSSON 1961 it occurred most often in moss but also in other kinds of media as leafy litter. In the soil it does not seem to penetrate into the layers underlying the litter in any considerable quantities. *Entomobrya nivalis* is a species which to a great extent lives up in the higher vegetation and not in the soil. Its occurrence in the higher and drier layers is therefore natural.

All the remaining species of the Hälsingland coniferous forest area show a more or less distinct preference for the deeper humus layer. This is of course most impressive for the typically deep-living, white and blind species *Tullbergia krausbaueri* and *Isotomiella minor*, but also species as *Lepidocyrtus lanuginosus*, *Onychiurus absoloni*, *Isotoma notabilis* and *Neanura muscorum*, which showed a certain preference for the litter layer in Sjöbo, show a distinct preference for the humus layer in Hälsingland. It is very probably a higher degree of desiccation of the soil in Hälsingland than in the other localities studied, which has caused the greater concentration of animals in the humus layer.

FORSSLUND (1944) studied the vertical distribution of the collembola, but he does not indicate the distribution of other single species than *Isotoma notabilis*, *Isotomiella minor* and *Folsomia fimetarioides*.

Isotoma notabilis occurs in his material most often in the litter layer and becomes more sparse with increasing depth. This is in accordance with my results from Sjöbo and Bökeberg but the results from Hälsingland show that the depth distribution may be different in different areas.

Isotomiella minor occurs most often in FORSSLUND's material in the humus and less often in the litter. This is in accordance with my re-

sults from Sjöbo and Hälsingland, but the results from Bökeberg show greater occurrence in the litter (cf also HAARLÖV 1960).

AGRELL (1941) studied the vertical distribution of collembola. He presented a survey of the species which predominantly occurred in litter and those which predominantly occurred in humus. His results as to species found in the present material were as follows (somewhat simplified):

Species that occur predominantly in litter	Species that occur predominantly in humus
Friesea mirabilis	*Onychiurus armatus*
Onychiurus absoloni	*Tullbergia krausbaueri*
Anurophorus laricis	*Isotomiella minor*
Folsomia quadrioculata	
Isotoma notabilis	
Isotoma viridis	
Isotoma olivacea	
Entomobrya nivalis	
Lepidocyrtus lanuginosus	
Willemia anophthalma	
Micranurida pygmaea	
Neanura muscorum	
Pseudanurophorus binoculatus	
Megalothorax minimus	
The *Symphypleona*	

It is seen that his results coincide very well with the present results with the exception of most of the species from Hälsingland. As already pointed out this is very probably due to the higher degree of desiccation of the soil in Hälsingland than in the other localities. AGRELL (1941) also points out that the vertical distribution of the collembola changes with changing moisture conditions (p. 36). It may be pointed out in this connection, that HAARLÖV (1960) came to the result that *Friesea mirabilis* had the same type of vertical distribution as *Tullbergia krausbaueri* (p.55).

It is evident from these comparisons that considerable differences may exist in the depth distribution of the same species between different

areas. Yet, several species always show the same preference for a higher or lower level in the soil. This seems to have a certain importance for the dietary habits of the different species and thereby for their soilbiological effect, and will be discussed in the following chapter.

3.2. Seasonal variation

The materials from the deciduous forest areas of Dalby Hage and Trollskogen and from the coniferous forest area of Bökeberg have been collected periodically, but not quite regularly, over a period of about three months (Trollskogen) to 9 months (Bökeberg). These periodical collections give some idea of the seasonal variation of the most common species in these three areas. In the following diagrams the population density is expressed as the mean number of specimens per sample at each date.

The three species *Folsomia quadrioculata, Isotoma notabilis* and *Lepidocyrtus lanuginosus* occur in all three areas in sufficient numbers as to be compared. *Folsomia quadrioculata,* which according to BÖDVARSSON (1961) has an extremely great power of propagation, occurs in both deciduous forest areas in rather small quantities from the end of March towards the end of April (10-20 specimens per sample. Figs. 1-2). But at the middle of May the population density rises suddenly to about 50 specimens per sample in Dalby Hage and about 70 in Trollskogen. It sinks again on the 8th of June ande the 13th of July (Dalby Hage) but there seems to be a general rising tendency towards the 4th of October.

Isotoma notabilis has somewhat different development in the two localities. In Trollskogen it has low density on March 12th (4 specimens per sample) but on April 2nd its population density has risen to 63 specimens per sample. On April 20th it has sunk to about 10 specimens per sample, but rises to about 30 specimens on May 21st.

In Dalby Hage the population density is also very low on March 12th but has not risen much on March 29th and on May 17th it is not more than about 18 specimens per sample. The density now sinks radically in Trollskogen to June 24th, when the registrations cease there but sink a little and rise again in Dalby Hage. After a further sinking on July 13th, there is a continuous rise in the population density of *Isotoma notabilis* until October 4th, when it attains about 80 specimens per sample.

The development of the population density of *Lepidocyrtus lanuginosus* is somewhat similar in both deciduous forest areas. It never reaches any high values (not 30 specimens per sample at most).

The development of the population densities in the coniferous forest area at Bökeberg (fig. 3) is somewhat different from that of the deciduous forest areas.The most impressive difference is the great population density of *Lepidocyrtus lanuginosus*, especially in the cold winter months (February 26th and March 3rd, when the density reaches 98 specimens per sample). The population density of *Lepidocyrtus lanuginosus* reaches tops on May 17th and August 25th (84 and 77 specimens per sample respectively). This is a very different development as compared with the deciduous forest areas.

Folsomia quadrioculata starts with small numbers on February 26th and has population tops on April 20th and July 13th but never comes up to more than 55 specimens per sample. It has very low population density on May 17th (then it had a population top in Dalby Hage) and on August 25th.

Isotoma notabilis also starts with low population density on February 26th but reaches 30-40 specimens per sample between March 6th and April 20th. It has low numbers on May 17th (then it had population tops in the deciduous forest areas) and on July 13th (then also at Dalby Hage). On August 25th it has its greatest population density under the whole period, 85 specimens per sample. At that time there was also a population top at Dalby Hage, but there it continued to rise, while it decreased at Bökeberg to 18 specimens per sample on November 9th.

No serious attempt will be made here to deduce the number of generations of a year from these curves. No measurements of the size of the individuals have been made so that it is impossible to say how great a proportion of the individuals at the population tops are juveniles. AGRELL (1941) deduced from his Lapland material, that *Folsomia quadrioculata* should have two generations a year. HAARLÖV (1960) deduces from his material from Denmark (similar latitude and climate as in Skåne), that *Folsomia quadrioculata* may have had a maximum of 4 generations in the year 1942 (p. 90). If the population tops of the curves for Bökeberg and Dalby Hage indicate great numbers of juvenile individuals, this means that the species has at least three generations a year in Skåne.

For *Isotoma notabilis*, AGRELL (1941) found two generations, one in spring and another in summer. In HAARLÖV's material of *Isotoma notabilis* from the Hawthorn Thicket (table XXVI), the population has peaks on dates 23/5, 29/6, 27/8 och 12/10. These dates agree pretty well with the dates for population peaks in Dalby Hage. This might indicate that this species also has at least three generations a year in Southern Sweden and Denmark. Such deductions on basis of the present material are, however, rather speculative, and will not be developed further here.

AGRELL (1941) found only one generation of *Lepidocyrtus lanuginosus* in Lapland. He found the newly hatched individuals in great numbers more or less immediately after the melting of the snow. This seems to agree with the great numbers of *Lepidocyrtus lanuginosus* in Bökeberg already on January 26th. Also this species seems to have at least three generations in Southern Sweden (three peaks of the curves for Bökeberg and Dalby Hage).

It is seen from these comparisons that the course of development of the population density is very different in different species and also in different soils. This has also been shown e.g. by AGRELL (1941) for Lapland collembola and by PALISSA (1959) for German meadow collembola. This fact, together with factors as the dietary habits of the different species, their different sizes and the amount of ingested food, must of course have great influence on the role that these animals play in the processes of breakdown of the litter and humus at different times of the year and should be regarded when estimating these (cf BÖDVARSSON 1970 and the following chapter).

4. Alimentary studies of the collembola of the Hälsingland forest area

Some alimentary studies have been made on the collembola from Hälsingland. As is seen from table 7, the six species *Anurophorus laricis*, *Friesea mirabilis*, *Tullbergia krausbaueri*, *Lepidocyrtus lanuginosus*, *Isotomiella minor* and *Onychiurus absoloni* occur in considerably greater number of specimens and samples than the others. The material of these species has been studied with respect to the amount of ingested food, and the amount of fungal hyphae eaten. Several other more general observations of the ingested food have been made and will be mentioned in the following text.

These studies have been made along the same lines as my alimentary studies of 1970 (BÖDVARSSON 1970). One of the most conspicuous results of these studies was, that a considerable proportion of all examined individuals have no gut contents at all (between 20.6 per cent for *Megalothorax minimus* and 51.5 per cent for *Lepidocyrtus lanuginosus*). As table 14 shows, the percentages of individuals without gut contents in the present material is still much greater than in my previous investigation. In my paper of 1970, I discussed the possible explanations of this high percentage of individuals without visible gut contents. The present extremely high percentages are still more perplexing and this is apparently a phenomenon which needs further examination, both experimental and otherwise. It is quite evident that the great number of empty guts which seems to be the rule in collembolan populations must be regarded in estimations of the soil-biological importance of these animals.

Another phenomenon which I also pointed out in my paper of 1970 and must be regarded, is the degree to which the guts of the animals with gut contents are filled. This has been calculated in the same way as in the paper of 1970: The number of body segments with gut contents has been counted, the percentage of segments with gut contents as compared with the number of all individuals with gut contents has been calculated and the mean percentage of those segments which most often are filled has been calculated. The results of these calculations are shown in table 15 which shows the percentages of segments with gut contents and the mean percentage indicating how great a part of the gut of that species is filled on the average. It is seen that *Tullbergia krausbaueri* has the greatest part of the gut filled, while *Friesea mirabilis* has the least. In my paper of 1970 I suggested that typical soil animals which prefer the deeper layers of the soil more often have filled guts than those living nearer the surface, because their food was qualitatively inferior to the food of the others. This seems to be corroborated by *Tullbergia krausbaueri* and *Onychiurus absoloni*, which are white and blind, but curiously enough *Lepidocyrtus lanuginosus* has more filled gut than *Isotomiella minor* in the present material, while *Lepidocyrtus*, being more surface-dwelling, had the least filled gut in the study of 1970, in accordance with the above-mentioned theory. This cannot be explained at the present time, but it may have something to do with the soil conditions in Hälsingland. As is seen from table 13, *Lepidocyrtus lanuginosus* is in fact more common and numerous in the humus than in the litter in Hälsingland.

As in the study of 1970, the amount of fungal hyphae in the gut was also studied in the present investigation. This was done in the same way as before: The amount was classified into the following four classes. 1. No fungal hyphae. 2. Single pieces of fungal hyphae here and there in the gut contents. 3. Fairly great quantity of fungal hyphae in the gut contents, but always mingled with considerable quantities of other substances. 4. Fungal hyphae almost the only or definitely the only ingredient of the gut contents (Table 16). It is seen that *Isotomiella minor* and *Anurophorus laricis* have the lowest number of individuals with no fungal hyphae, i.e. they have the greatest quantity of fungal hyphae in their guts. All the others have much less. In my study of 1970 I concluded that there seemed to exist a certain contrasting relationship between the amount of ingested food and fungal hyphae. The more superficially the species lived, the less amount of food eat the individuals and the greater was the fungal component of the food consumed. It is seen from table 15, that *Tullbergia krausbaueri*, *Onychiurus absoloni*, *Lepidocyrtus lanuginosus* and *Isotomiella minor* (all humus-living in the present material according to table 13) have considerably more food in their guts than *Anurophorus laricis*, which lives nearer the surface. According to table 16, the species *Tullbergia krausbaueri*, *Onyciurus absoloni* and *Lepidocyrtus lanuginosus* have considerably less amounts of fungal hyphae in their guts than *Anurophorus laricis*, which thus corroborates the above mentioned theory. *Isotomiella minor* is an exception in this material. It is a rather deep-living species (table 13), but non the less has eaten the greatest quantities of fungal hyphae. The number of *Friesea mirabilis* with gut contents was so small (cf table 14), that the calculations on this species are less reliable. Most of the gut contents observed in this species consisted of a semi-transparent mass. This indicates a special kind of food, which perhaps is not always visible in the gut in ordinary preparations. GISIN (1960) indicates that the species probably is a predator of *Radiolarians* etc.

5. Summary

Analyses of the qualitative and quantitative composition of the collembolan faunas of deciduous and coniferous foersts have given the following results.

It is impossible to designate any distinct species as a characteristic specialist of the litter and humus of deciduous forests in Southern Sweden. Quantitativley dominant are great ubiquists as *Isotoma notabilis, Lepidocyrtus lanuginosus, Folsomia quadrioculata, Isotomiella minor* and *Onyciurus armatus*. A considerable amount of species occur very sporadically and are found in a single or a pair of samples and cannot therefore be characteristic of the soil type. The remainder are more or less ubiquitous species of less common occurrence than the great ubiquists.

The collembolan fauna of thin sheets of moss on beech-bark is characterized by a series of species which are more of less specialized on this medium. Among these are *Pseudisotoma sensibilis*, which prefers mossy vegetation of different kinds, *Friesea claviseta, Xenylla börneri* and *Entomobrya corticalis*.

The collembolan fauna of coniferous forests is somewhat more specialized than that of deciduous forests. The great ubiquists *Lepidocyrtus lanuginosus, Isotoma notabilis, Folsomia quadrioculata, Tullbergia krausbaueri, Friesea mirabilis* and *Isotomiella minor* are generally dominating but species which are uncommon in other surroundings may become quite conspicuous in certain areas (*Xenylla humicola* in Sjöbo, Southern Sweden, *Anurophorus laricis* in Hälsingland, Northern Sweden, and *Onychiurus absoloni* in all three areas studied. The last species seems to have a certain preference for coniferous forests).

The collembolan fauna of spruce cones turned out to be very generalized, all important species of this fauna being typical ubiquists, possibly with the exception of *Onychiurus absoloni*, which accoring to the above-stated shows some preference for coniferous forests.

Studies of the depth distribution of the species in the different areas has shown that considerable differences may exist in the depth distribution of the same species between different areas. Several species always show, however, the same preference for a higher or a lower level in the soil. Thus, in the deciduous forest areas, the species *Isotoma notabilis, Folsomia quadrioculata, Lepidocyrtus lanuginosus, Onychiurus furcifer, Tomocerus flavescens* and *Neanura muscorum* occur predominantly in the litter layer, while the species *Isotomiella minor, Onychiurus armatus* and, expecially, *Tullbergia krausbaueri*, prefer the humus layer.

In the coniferous forest areas the depth distribution of the species is more varying. The very common and ubiquitous species *Lepidocyrtus lanuginosus*, *Isotoma notabilis*, *Onychiurus armatus* and *Isotomiella minor* may occur predominantly in both the litter and the humus layers of different areas. The same is the case with *Onychiurus absoloni* and *Neanura muscorum*. *Tullbergia krausbaueri* always occurs predominantly in the humus layer.

Studies of the seasonal variations of three of the most common species, *Folsomia quadrioculata*, *Isotoma notabilis* and *Lepidocyrtus lanuginosus*, show that the course of development of the population density is very different in different species and in different soils. This must have great influence on the role that these animals play in the processes of breakdown of the litter and humus at different times of the year and should be regarded when estimating these.

Some alimentary studies were made of the collembola of Hälsingland. The results of these may be summarized as follows:

1. A very high proportion of the individuals of the collembolan populations have no gut contents at all (between 63.8 and 97.6 per cent in the present material; table 14). This is a phenomenon which needs further study, both experimental and otherwise. It is quite evident that the great number of empty guts, which seems to be the rule in collembolan populations, must be regarded in estimations of the soil-biological importance of these animals.

2. Those animals which have eaten something, have in general only a part of their guts filled (between 41.0 and 77.9 per cent on the average; table 15). I have drawn the conclusion that typical soil animals which prefer the deeper layers of the soil, more often have filled guts than those living nearer the surface, because their food is qualitatively inferior to the food of the others.

3. Some studies of the amount of fungal hyphae in the gut have been made in the present investigation. The result is that the species *Isotomiella minor* and *Anurophorus laricis* have the greatest quantity of fungal hyphae in their guts. All the others have much less. My theory presented in the work of 1970, that there seemed to exist a certain contras-

ting realtionship between the amount of ingested food and fungal hyphae, seems to be corroborated by the present material. *Tullbergia krausbaueri*, *Onychiurus absoloni*, *Lepidocyrtus lanuginosus* and *Isotomiella minor* (all humus-living in the material studied) have considerably more food in their guts than *Anurophorus laricis*, which lives nearer the surface. *Tullbergia krausbaueri*, *Onychiurus absoloni* and *Lepidocyrtus lanuginosus* have considerably less amounts of fungal hyphae in their guts than *Anurophorus laricis*. *Isotomiella minor* is, however, an inexplicable exception to this rule.

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Table 1. The collembolan fauna of Dalby Hage (deciduous forest) 27 samples. 32 species.

	No. of samples	Total no. of specimens
Folsomia quadrioculata	26	1875
Isotoma notabilis	24	955
Lepidocyrtus lanuginosus	24	425
Onychiurus furcifer	23	298
Isotomiella minor	18	331
Tomocerus flavescens	15	82
Sminthurinus aureus	12	93
Hypogastrura purpurescens	10	19
Neelus minutus	9	46
Isotoma olivacea	8	17
Megalothorax minimus	8	35
Dicyrtoma minuta	8	46
Neanura muscorum	6	13
Onychiurus armatus	4	13
Micranurida pygmaea	3	4
Willemia aspinata	3	4
Dicyrtoma fusca	3	4
Pseudachorutes subcrassus	2	3
Pseudisotoma sensibilis	2	2
Folsomia litsteri	2	3
Pseudosinella alba	2	2
Pseudachorutes parvulus	1	1
Xenylla maritima	1	1
Xenylla börneri	1	1
Friesea mirabilis	1	1
Willemia anophthalma	1	6
Tullbergia krausbaueri	1	2
Onychiurus absoloni	1	3
Isotoma violacea	1	3
Isotoma bipunctata	1	1
Isotoma viridis	1	1
Heteromurus nitidus	1	1

Table 2. The collembolan fauna of Trollskogen (deciduous forest) 20 samples. 35 species.

	No. of samples	Total no. of specimens
Isotoma notabilis	18	479
Lepidocyrtus lanuginosus	18	301
Folsomia quadrioculata	17	710
Isotomiella minor	17	494
Tullbergia krausbaueri	16	231
Onychiurus armatus	15	197
Tomocerus flavescens	14	60
Neanura muscorum	12	20
Friesea mirabilis	11	47
Onychiurus furcifer	11	175
Pseudosinella alba	10	17
Megalothorax minimus	8	25
Micranurida pygmaea	7	9
Willemia anophthalma	7	203
Isotoma viridis	7	37
Sminthurinus aureus	7	23
Tullbergia callipygos	6	57
Pseudanurophorus binoculatus	6	16
Anurida granulata	4	29
Onychiurus absoloni	4	8
Micranurida forsslundi	3	3
Folsomia litsteri	3	7
Xenylla börneri	2	46
Willemia aspinata	2	65
Pseudachorutes parvulus	2	2
Orchesella cincta	2	2
Pseudisotoma sensibilis	1	1
Entomobrya nivalis	1	1
Entomobrya albocincta	1	1
Entomobrya corticalis	1	34
Orchesella bifasciata	1	1
Orchesella flavescens	1	1
Sminthurinus elegans	1	1
Sminthurus fuscus	1	1
Sminthurus lubbocki	1	1

Table 3. Forms common to both deciduous forest areas studies (Dalby Hage and Trollskogen)

1. *Isotoma notabilis*
2. *Lepidocyrtus lanuginosus*
3. *Folsomia quadrioculata*
4. *Isotomiella minor*
5. *Onychiurus armatus*
6. *Tullbergia krausbaueri*
7. *Megalothorax minimus*
8. *Isotoma viridis*
9. *Pseudosinella alba*
10. *Friesea mirabilis*

11. *Onychiurus furcifer*
12. *Tomocerus flavescens*
13. *Sminthurinus aureus*
14. *Neanura muscorum*
15. *Micranurida pygmaea*
16. *Willemia aspinata*
17. *Pseudisotoma sensibilis*
18. *Folsomia litsteri*
19. *Pseudachorutes parvulus*
20. *Xenylla börneri*
21. *Willemia anophthalma*
22. *Onychiurus absoloni*

Table 4. The collembolan fauna of pieces of beech-bark with thin sheets of green moss. 4 samples. 16 species.

	No. of samples	Total no. of specimens
Pseudisotoma sensibilis	4	164
Lepidocyrtus lanuginosus	4	29
Friesea claviseta	3	54
Xenylla börneri	3	2120
Onychiurus absoloni	2	2
Tomocerus minor	2	3
Entomobrya corticalis	2	23
Onychiurus furcifer	1	1
Folsomia quadrioculata	1	9
Vertagopus cinerea	1	3
Isotoma notabilis	1	12
Isotoma violacea	1	2
Lepidocyrtus cyaneus	1	3
Entomobrya nivalis	1	2
Oschesella bifasciata	1	15
Orchesella cincta	1	1

Table 5. The collembolan fauna of Bökeberg (coniferous forest)
34 samples. 32 species.

	No. of samples	Total no. of specimens
Lepidocyrtus lanuginosus	34	2126
Isotoma notabilis	31	1031
Folsomia quadrioculata	27	1132
Tullbergia krausbaueri	17	89
Friesea mirabilis	16	159
Onychiurus absoloni	16	81
Isotomiella minor	16	81
Onychiurus armatus	10	60
Isotoma viridis	9	19
Lepidocyrtus cyaneus	8	22
Pseudosinella alba	8	36
Willemia anophthalma	6	22
Entomobrya nivalis	6	71
Xenylla brevicauda	5	45
Megalothorax minimus	4	6
Hypogastrura purpurescens	3	16
Micranurida pygmaea	3	10
Neanura muscorum	3	10
Folsomia litsteri	3	6
Entomobrya corticalis	3	4
Xenylla börneri	2	3
Tullbergia callipygos	2	4
Sminthurinus aureus	2	2
Hypogastrura manubrialis	1	2
Pseudachorutes parvulus	1	1
Willemia aspinata	1	1
Xenylla mucronata	1	36
Onychiurus ambulans	1	3
Folsomia fimetaria	1	1
Orchesella cincta	1	1
Sminthurides pumilis	1	4
Sminthurus fuscus	1	2

Table 6. The collembolan fauna of Sjöbo (coniferous forest).
10 samples. 17 species

	No. of samples	Total no. of specimens
Isotoma notabilis	8	350
Isotomiella minor	7	113
Xenylla humicola	6	112
Neanura muscorum	5	9
Onychiurus absoloni	5	8
Tullbergia krausbaueri	4	36
Onychiurus armatus	4	10
Lepidocyrtus lanuginosus	4	22
Tomocerus flavescens	3	5
Megalothorax minimus	3	3
Entomobrya nivalis	2	2
Sminthurus fuscus	2	3
Hypogastrura purpurescens	1	13
Micranurida pygmaea	1	1
Folsomia quadrioculata	1	1
Isotoma olivacea	1	20
Sminthurinus aureus	1	2

Table 7. The collembolan fauna of Långmor, Hälsingland (coniferous forest). 36 samples. 21 species.

	No. of samples	Total no. of specimens
Anurophorus laricis	36	1489
Friesea mirabilis	22	289
Tullbergia krausbaueri	21	135
Lepidocyrtus lanuginosus	20	210
Isotomiella minor	13	109
Onychiurus absoloni	11	61
Isotoma notabilis	9	23
Isotoma viridis	7	13
Willemia anophthalma	6	20
Neanura muscorum	6	12
Micranurida pygmaea	5	30
Xenylla börneri	5	431
Pseudanurophorus binoculatus	5	64
Isotoma violacea	5	18
Micranurida forsslundi	4	6
Entomobrya nivalis	3	9
Willemia aspinata	2	8
Pseudachorutes parvulus	1	5
Pseudisotoma sensibilis	1	1
Orchesella flavescens	1	1
Bourletiella hortensis	1	1

Table 8. The collembolan fauna of Bökeberg (spruce cones).
5 samples. 19 species.

	No. of samples	Total no. of specimens
Lepidocyrtus lanuginosus	5	108
Onychiurus absoloni	4	35
Isotoma notabilis	4	104
Tullbergia krausbaueri	3	3
Folsomia quadrioculata	3	116
Isotomiella minor	3	6
Hypogastrura purpurescens	2	69
Neanura muscorum	2	2
Friesea mirabilis	2	31
Isotoma olivacea	2	2
Entomobrya nivalis	2	8
Pseudachorutes parvulus	1	7
Pseudachorutes corticicolus	1	1
Xenylla börneri	1	2
Xenylla grisea	1	9
Isotoma viridis	1	1
Entomobrya corticalis	1	4
Sminthurus lubbocki	1	2
Sminthurus fuscus	1	2

Table 9. Depth distribution of the collembola of Dalby Hage (deciduous forest).

	Litter		Humus	
	No. of samples	No. of specimens	No. of samples	No. of specimens
Folsomia quadrioculata	16	1039	18	702
Isotoma notabilis	13	674	15	155
Lepidocyrtus lanuginosus	15	243	11	71
Onychiurus furcifer	12	183	16	74
Isotomiella minor	10	142	12	123
Tomocerus flavescens	12	59	3	12
Sminthurinus aureus	5	60	5	10
Hypogastrura purpurescens	6	8	1	2
Neelus minutus	6	33	5	12
Isotoma olivacea	5	9	3	4
Megalothorax minimus	4	23	3	3
Dicyrtoma minuta	3	22	3	10

Table 10. Depth distribution of the collembola of Trollskogen (deciduous forest).

	Litter		Humus	
	No. of samples	No. of specimens	No. of samples	No. of specimens
Isotoma notabilis	10	226	11	41
Lepidocyrtus lanuginosus	11	187	3	6
Folsomia quadrioculata	7	459	9	37
Isotomiella minor	9	127	10	176
Tullbergia krausbaueri	4	36	8	138
Onychiurus armatus	3	35	10	76
Tomocerus flavescens	8	34	1	1
Neanura muscorum	5	11	3	3
Friesea mirabilis	2	6	4	7
Onychiurus furcifer	6	88	1	2
Pseudosinella alba	2	3	4	4

Table 11. Depth distribution of the collembola of Sjöbo (coniferous forest).

	Litter		Humus	
	No. of samples	No. of specimens	No. of samples	No. of specimens
Isotoma notabilis	5	200	5	27
Isotomiella minor	3	6	4	23
Xenylla humicola	4	69	-	-
Neanura muscorum	3	6	1	1
Onychiurus absoloni	4	5	-	-
Tullbergia krausbaueri	-	-	2	3
Onychiurus armatus	-	-	4	10
Lepidocyrtus lanuginosus	4	17	1	5

Table 12. Depth distribution of the collembola of Bökeberg (coniferous forest).

	Litter		Humus	
	No. of samples	No. of specimens	No. of samples	No. of specimens
Lepidocyrtus lanuginosus	13	974	8	43
Isotoma notabilis	12	287	6	54
Folsomia quadrioculata	11	640	7	53
Tullbergia krausbaueri	7	19	9	51
Friesea mirabilis	5	42	5	50
Onychiurus absoloni	5	6	3	5
Isotomiella minor	7	32	3	3
Onychiurus armatus	4	30	3	7
Isotoma viridis	5	6	-	-
Lepidocyrtus cyaneus	4	11	-	-
Pseudosinella alba	3	12	4	4

Table 13. Depth distribution of the collembola of Långmor, Hälsingland (coniferous forest).

	Litter		Humus	
	No. of samples	No. of specimens	No. of samples	No. of specimens
Anurophorus laricis	23	678	23	432
Friesea mirabilis	7	34	13	209
Tullbergia krausbaueri	5	14	16	114
Lepidocyrtus lanuginosus	7	78	12	101
Isotomiella minor	3	4	11	103
Onychiurus absoloni	3	12	10	46
Isotoma notabilis	2	5	6	13
Isotoma viridis	1	1	4	10
Willemia anophthalma	3	7	4	13
Neanura muscorum	1	1	5	8
Micranurida pygmaea	1	1	4	29
Xenylla börneri	4	399	1	31
Pseudanurophorus binoculatus	2	10	4	54
Isotoma violacea	2	3	4	15
Micranurida forsslundi	1	1	3	5
Entomobrya nivalis	2	8	-	-

Table 14. Percentages of individuals without gut contents. Coniferous forest, Hälsingland.

	No. of specimens	No. of samples	Percentages
Friesea mirabilis	289	25	97.6
Anurophorus laricis	1489	54	96.5
Tullbergia krausbaueri	135	23	91.8
Lepidocyrtus lanuginosus	210	24	78.0
Isotomiella minor	109	15	73.4
Onychiurus absoloni	61	14	63.8

Table 15. Proportions of the body segments having gut contents, calculated as percentages of all individuals that have any gut contents in any segment.
M = means of these percentages, indicating how great a percentage of the gut of that species is filled on the average.

	th.I	th.II	th.III	abd.I	abd.II	abd.III	abd.IV	abd.V	M
Tullbergia krausbaueri	-	54.5	90.9	100.0	100.0	100.0	72.7	27.2	77.9
Onychiurus absoloni	13.6	63.6	72.7	86.3	86.3	86.3	72.7	13.6	61.9
Lepidocyrtus lanuginosus	-	39.1	58.7	69.6	87.0	71.7	24.0	-	58.4
Isotomiella minor	10.5	57.9	79.0	79.0	89.5	68.4	21.1	-	57.9
Anurophorus laricis	-	25.0	55.8	75.0	73.0	55.8	21.2	-	51.0
Friesea mirabilis	-	-	14.3	14.3	28.6	28.6	85.7	71.4	41.0

Table 16. Amounts of ingested fungal hyphae. Percentages of all individuals that have gut contents.

	No fungal hyphae	Single pieces of fungal hyphae here and there in the gut contents	Fairly great quantity of fungal hyphae in the gut contents, but always mingled with considerable quantities of other substances	Fungal hyphae almost the only or definitely the only ingredient of the gut contents
Isotomiella minor	21.1	31.2	47.4	-
Anurophorus laricis	26.9	38.5	34.6	-
Onychiurus absoloni	63.6	27.3	9.1	-
Lepidocyrtus lanuginosus	69.6	17.4	10.9	2.2
Tullbergia krausbaueri	81.8	9.1	9.1	-
Friesea mirabilis	85.7	-	14.3	-

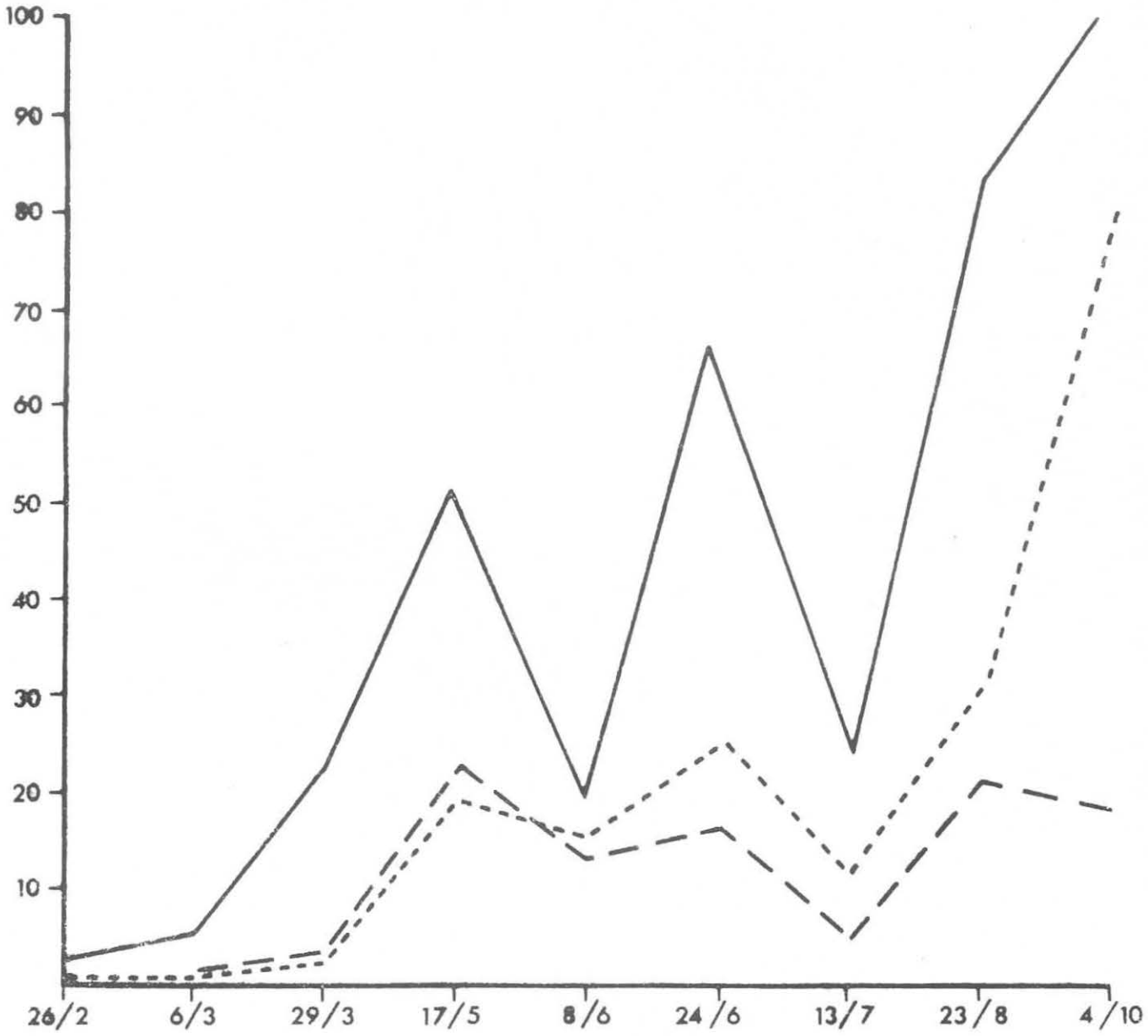

Fig. 1. Seasonal variations in the population density of the species *Folsomia quadrioculata*, *Lepidocyrtus lanuginosus* and *Isotoma notabilis* at Dalby Hage (deciduous forest). The population density is expressed as the mean number of specimens per sample in the ordinates.

——— *Folsomia quadrioculata*

— — — *Lepidocyrtus lanuginosus*

-------- *Isotoma notabilis*

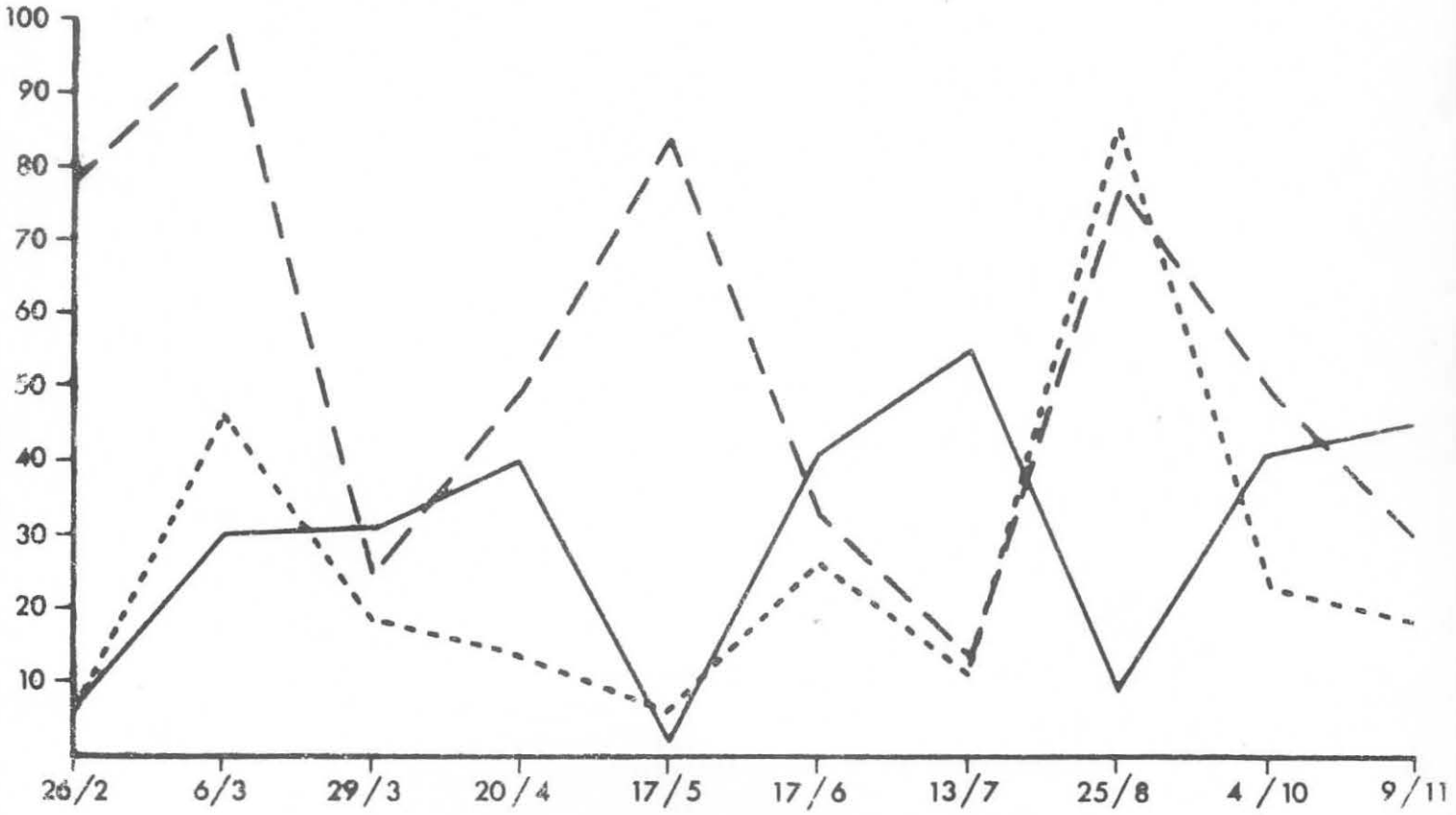

Fig. 3. Seasonal variations in the population density of the species *Folsomia quadrioculata*, *Lepidocyrtus lanuginosus* and *Isotoma notabilis* at Bökeberg (coniferous forest). The population density is expressed as the mean number of specimens per sample in the ordinates.

———— *Folsomia quadrioculata*

— — — *Lepidocyrtus lanuginosus*

-------- *Isotoma notabilis*